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## THE SO-CALLED MOTOR AREA OF THE CORTEX.\*

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Since rational methods of investigation have revealed to us any real knowledge of the functions of the cerebral cortex, it has been customary to speak of the motor and sensory regions of the brain or of the cortex. It was Hughlings-Jackson, I believe, who first named the "motor area," and to-day he is one of the strongest adherents of the view that a portion of the cortex has a purely motor function. The idea that the anterior part of the brain had a motor, and the posterior a sensory function is a very old one; indeed it dates back even to the time of Galen. This idea was confirmed by analogy after the brilliant work of Bell and others in the anatomy and physiology of the cord. With this strongly preconceived notion of the dual nature of the function of the nervous system the majority of investigators in the problem of cerebral physiology have gone to work. While by a few more or less protest has been made to an acceptance of this view, of a motor as well as sensory function of the cortex, the opponents of the motor theory seem to be yet in the minority both among physiologists and psychologists. Yet, within the last five years it seems to me that the two sides find more and more in common and the dispute is fast being reduced to a mere dispute in names. Those opposed to the view that consciousness could result from activity of motor cell, found their first weapon of attack in the muscular sense. Bain in England and Wundt in Germany in their works on psychology met the problem of the feeling of effort, of energy expended, in this way. We are conscious, they said, of an outgoing impulse; at the instant of innervation we are conscious of so much energy expended. For it was clear that this feeling is not an impression received along the channels of the classical five senses. Within a few weeks of each other, Bastian in England and Wm. James of Harvard published views opposed to Bain on this matter. Prof. James's now famous thesis entitled "The Feeling of Effort," almost if not quite completely overthrew Bain's hypothesis. Wundt in his later work has modified his view somewhat, taking

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a middle course admitting that the feeling of effort is largely sensory, but holds that there is a motor element in it. It is all but universally admitted that there is a muscular sense; the dispute to-day is merely what part the recorded muscular sense impressions play in consciousness and will, functions as we believe of the cerebral cortex. A most interesting discussion in the London Neurological Society was held after a paper by H. Charlton Bastian on the subject of the "Muscular Sense; its Nature and Cortical Localization." This was reported in full in *Brain* for April, 1887. This represented fairly, it is to be presumed, the position of English neurologists and physiologists on this question. Bastian stands almost alone in his position that there is no strictly motor function of the cortex; that all motor cells lie below the superficies of the brain; that the so-called motor region is as purely sensory as any part of the cortex. Bastian's term is "kinæsthetic," which term for its convenience I shall use in this paper. "Kinæsthetic" as used by Bastian includes more than what is meant by the muscular sense strictly. It means the sensation of movement, and includes usually tactile and joint sensations, all sensation whether from muscle, skin, ligaments, tendons, or joint surfaces that are the result of a muscular contraction and consequent movement. Yet it is probable that the muscular sense proper is the chief factor of the kinæsthetic sense. Opposed to Bastian most strenuously is Ferrier, who will not admit the cortical localization of the muscular sense. It is interesting just here, however, to note that Ferrier in the first edition of "Functions of the Brain," while he took a positive stand against the theory of Bain and others and declared that we could have no sensation not centripetal in origin, denied that few objects were known to us by sensory impressions only. This apparently strangely contradictory position has been frequently criticised. I remember many years ago as a student being strangely puzzled by that chapter. But in his second edition he has expressed himself more consistently—(Bastian claims he has changed front, but this he strenuously denies)—and he says the motor centres are the organic bases of motor acquisitions. But he still is opposed to the view that the motor centres are concerned directly with consciousness. Their relation to consciousness is simply in arousing the sensory centres by association. Others present at this meeting took various intermediate positions, but there seemed to be no uniformity of opinion on this most interesting question. Before entering further upon this

discussion let us hastily review the evidence on this subject. Our knowledge of the physiology of the cortex is derived from two sources: experimentation on lower animals, and clinical and pathological study in man. The methods of work on the lower animals have been essentially the same from Hitzig and Fritsch and Ferrier to Horsley. The differences are in the greater refinement of details.

The work on animals consists of studying the symptoms subsequent to ablation of portions of the cortex, and watching the movements made after stimulation of definite regions with the electrical current. Horsley's experiments are, as is to be expected, the most accurate and reliable, he having had the advantage of the work of his predecessors, and of more careful methods, such as antiseptis. But it does not appear that his work, while of marked benefit to cerebral surgery, has added materially to our knowledge of cerebral physiology. The facts resulting from laboratory experiments are for the most part admitted by all. There is as might be expected a wide difference in the inferences drawn therefrom.

From this class of experiments it is established that a definite relation exists between certain well defined points in that part of the cerebral cortex lying about the fissure of Rolando and certain voluntary muscles or groups of muscles; that electrical stimulation of these points in the cerebrum is usually followed by a contraction of the corresponding muscle or group of muscles; also that voluntary motion is suspended in whole or in part after removal of this portion of the cortex.

It is also established further that this so-called motor area is essential to voluntary movement.

But we shall not find our conclusions concerning the action of a normal human brain drawn from phenomena observed on stimulating the brain of an etherized animal go unchallenged. The conditions are so widely different that we must look to clinical study and pathological research to confirm all we dare claim to know of human cerebral physiology. But in this field progress must necessarily be slow. The lesions are not made by the observer, nor can the symptoms be studied by those who hold opposite theories. It is unavoidable that the reporter's preconceived theories should not color his observation and inferences. The study of aphasia or speech disturbances has given us the most valuable information we possess in the question of cerebral



physiology from the clinico-pathological side, and for the purposes of this discussion it will be sufficient to confine ourselves to the study of language, laying aside consideration of the trunk, and limb muscles and their respective "motor centres."

When Broca announced his truly remarkable discovery that loss of speech was in certain cases accompanied by a lesion in the posterior third of the third frontal convolution, a most important step was made in the study of cerebral physiology.

Some years later Wernicke was able to describe a form of speech disturbance, clinically and pathologically distinct from that in Broca's cases.

This has been called (unfortunately so, as it seems to me) sensory aphasia or amnesia; and to distinguish the two, the first described by Broca is spoken of as ataxic or motor aphasia. It is this term *motor aphasia* with which I am disposed to find fault. It seems to me to be as purely sensory as any form described. But I will return to the point later. Still further study and analysis of cases of speech disturbance has led to several more forms of psychical speech disturbance, with a more or less complete localization of the corresponding cerebral lesion. I trust I may be pardoned if I hastily review the already well-beaten path, namely, the psychology of speech. When a word is heard there is, it is safe to say, an excitation of the cerebral cortex in a region more or less sharply defined. This region has been called the auditory *word* centre, as it is supposed that words are recorded in a region by themselves, distinct from other sounds perceived. When this word (let us say the word *bell*) is repeated by the hearer, there is in addition to the auditory sensation of the voice of the speaker a sensation of various muscular movements, movements of lips, tongue, larynx, etc., and combined with them certain tactile sensations and possibly a third element of joint sensation. In other words, coincident with the auditory sensation is the complex kinæsthetic sensation. It is not necessary to suppose that the tactile element and the muscular element of this sensation have a different location in the cortex, in fact there is evidence that it is not the case. We do not analyze our movements; we feel them as one thing, a thing done, a word spoken. It is fair to suppose these auditory and kinæsthetic sensations of the word *bell* are recorded in two distinct places, topographically, though strongly linked together with associating fibres. So that when one image is revived the other is also necessarily. It is probable that silent thought is conducted

by means of these closely related word images, more especially by the auditory, however. When a person learns to read or write there become associated with these primary sense images a visual image of the written or printed word and one more kinæsthetic image of the act of writing the word. These later acquired images are appendaged as it were to the others and are not essential to, nor probably involved in, silent thought or speech. Still we frequently meet with disturbances of writing and reading that throw much light on the phenomena of brain action. Still further, when one learns to speak and write other languages than his own the number of new associations and images becomes greater, and it is bewildering to think of the net-work of brain associations in the man who can speak fourteen languages. It must not be forgotten that our idea of the object *bell* is again a complex affair made up of visual tactile kinæsthetic, temperature and auditory impressions. It is now evident that an idea or concept cannot be said to be limited to a definite spot in the cortex, but it is spread out over almost its entire area. Hence the notion of an ideational centre seems hard to understand, and so far as I know there are no clinical facts that call for any such centre. It is now evident, if we are right so far, that lesions in various parts of the cerebral cortex may be expected to cause disturbances of speech, and this is the case. There are four varieties well defined, *i. e.*, "motor aphasia," agraphia, word deafness, word blindness. There is still left unclassified a large number of cases presenting a variety of symptoms, all to be grouped under the term sensory aphasia, taking this term in its present restricted sense, which cannot be yet well defined. Bastian describes many such cases as *commissural amnesia*. We have seen that in a person who knows how to read and write the idea is fourfold. A lesion in the auditory visual cheiro-kinæsthetic or glosso-kinæsthetic areas or in any of the communicating fibres or in fibres associating the word idea with the object idea, will give rise to speech disturbance. A destruction of the auditory word centre will give rise to a condition where the person will not recognize a familiar word. We say he is psychically deaf, but he may not be deaf to familiar sounds: he may recognize the sound of a musical instrument or a tune. In this case the lesion in several cases has been found in the posterior half of the upper or second temporal convolution. Should fibres leading from and to the kinæsthetic centres be impaired it would be impossible to repeat or write from dictation, while it



would be possible to talk or write. There are yet two centres, the glosso-kinæsthetic or Broca's centre and the cheiro-kinæsthetic or writing centre, to be considered. Nothing is more certainly established in connection with this subject than that a lesion in Broca's region is followed by the difficulty known as motor aphasia. The "centre" corresponding to agraphia has not been definitely located yet, many cases indicating a commissural lesion in the track connecting the visual word centre, ~~with~~<sup>with</sup> the hand centre. But it must not be forgotten that if, as we have assumed, so large a portion of the cerebral area is involved in the function of language, and the so-called centres occupy so small a relative portion that *a priori* we should expect to find the greater number of lesions to be commissural rather than central. Do the results of electrical stimulation prove the area in question to be a motor area? Munk, who has made many such experiments, thinks not—he believes it to be a sensory centre; while Ferrier and his school, who have made an enormous number of similar experiments, are equally certain that their results show it to be a motor centre and not directly concerned in consciousness. Because a certain movement follows electrical excitation of a certain point in the cortex it does not follow that this brain area is in health the seat of a voluntary impulse for the contraction of its corresponding muscle. Still less does it prove that this area is motor rather than sensory.

For Munk and Schäfer and many others have demonstrated beyond all question that stimulation of what is admitted by all to be a sensory centre, the occipital lobe, the centre for vision, is followed by movements of the eyes and head. But taking this method together with the results of ablation of parts of the cortex, we are warranted in drawing many more inferences, at least as regards animal physiology. On looking through Horsley's recent reports to discover what new light if any had been shed on this question, I found he did not make a serious attempt to solve this question; but he mentions that in one or two instances he made an experiment with reference to the physiology of this region. But as he himself says they prove nothing. He attempted to test the muscular sensibility of an ape after removing or cutting the cortex. How can we test the muscular sense on a dumb animal? Such a test cannot be made. Again he appears to mistake the theory of the physiology of the cortex entirely. No physiologist contends so far as I know that sensations may not be received and motions result independently of the cortex. The cortex is the seat of



remembered sensations, the seat of voluntary movements. For that reason all such tests must be made on a human being whose mind is sufficiently clear to express his states of consciousness or be capable of voluntary action. The criticism made on some of Mr. Horsley's deductions regarding the thumb centre by Brown-Séquard, while sarcastic, is perfectly just. He says it does not follow because the thumb moves after electrical excitement of a certain point in a certain convolution that that is the centre of movement for the thumb. As well say that the centre of laughing is in the sole of the foot, because irritation of that point is followed by laughter.

This entire series of experiments on animals is subject to this criticism, but we do not base our theories of cortical function on so slight a foundation. As I have already said we must admit that there is a close physiological relation existing between these cortical areas and the various muscular groups. It is admitted that we have a muscular sense. It is admitted that certain areas of the cortex are storehouses for visual and auditory sensations. No adequate area has yet been defined for reception of tactile sensations. And almost no space at all for the muscular sense. It would not be unreasonable to suppose that for senses having so large a peripheral area there would be a considerable cortical area. But this is a mere conjecture. But on reviewing the experiments on animals there appears to me no objection to considering this region a sensory region; whether muscular or combined muscular and tactile it does not matter. But what evidence do we get from clinical examination? We have for the sake of simplicity limited the discussion to the various forms of aphasia. Here we find a patient no longer recognizes spoken words, we say he is psychically deaf, not deaf, but there is a forgetfulness of spoken words; the sound arouses no association, it is a sensory aphasia. It is true the lesion here may be not alone in the cortical cells, but in the channels adjacent, either ingoing or outgoing. We have seen that the lesions in several such cases are in the places where we should expect to find them from the result of the physiologist. And so in case of word blindness, there is a forgetfulness of written words, a *sensory* aphasia. Let us for the sake of an argument assume that Broca's convolution is a kinæsthetic sense region. What would we expect of this region should it be thrown by disease out of connection with the rest of the cortex? What would we expect as the result? The patient could think, could understand spoken

and written words, but he could not use the acquired faculty of speech. He would have forgotten how to speak. Voluntary articulation would be lost. Here too is a forgetfulness. The patient is in the same condition as a child a year or two old who has not begun to talk (except for the matter of reading.) The child has not acquired the faculty, the aphasic man has lost his. As the idea of a muscular sense renders the psychology of sensation so much more simple, so does it seem to me that if we accept the idea of the Rolandic area being a sensory area we have a much simpler view of the physiology of the cortex and in no way do violence to the accepted facts in physiology or clinical medicine. We have seen how complex are the simplest ideas we possess of external objects; it is seldom composed of less than four sensory elements and at times of as many as six if not seven or eight. All ideas of words have, if we call the kinaesthetic sense one, *two* elements; if we divide it then we must say three or even four; and in the mind of one who can read and write there are two more elements. Then too our idea of size of an object as judged by the eye is composed of the retinal impression intimately associated with the impression from the ocular muscles. This association is so close and so constant the combined impression must be considered as one. If then the kinaesthetic element (or motor element if you choose) enters so largely into our sense impressions of external objects and their names, we must either admit of most ideas being *sensori-motor*, or else consider the so-called motor elements really a sensory element. If we consider the motor feeling as something radically different from other feeling, then we must consider most impressions to have this dual character. And in fact this is the position recently taken by a few writers. But it seems to me much more simple and consistent, and for that reason wiser, to consider the cortex as entirely (so far as explored) a sensory region, the seat of memory and the will. And as I have already said psychologists are rapidly coming to more harmonious views of cerebral action, and the disputes seem after all to belittle better than a contention for names. But there is still one more consideration. We know that in perverted action of the brain we have hallucinations, or vivid revivals of stored sensations. Do we have hallucinations of the muscular sense? Verbal auditory hallucinations are very common. Do we have kinaesthetic hallucinations? Hallucinations of the muscular sense are very frequent, as is well known, with those who have lost a limb. Cramped positions,



and movements felt are described by a very large proportion of those who have lost a limb, according to the statistics collected by William James. Since I have been asked to write a paper for this meeting I have been surprised and most highly delighted to have come across a recent paper by Tamburini, (translated by Workman), on the subject of "Motor Hallucinations." *Motor hallucinations*—here again we have a strange inconsistency. An hallucination is sensory surely; how much better to regard such as an hallucination of a sense of movement, as there is no denying that movements give rise to a sensation. But the cases collected and described by Tamburini are so unique and extremely interesting that I must quote from his paper. He says: "The theory advanced by me in 1880 and now fully accepted, that hallucinations essentially consist in an *imitative state of the psycho-sensory centres of the cerebral cortex*;" and further on, "the undoubted fact that the mental image of a word consists of three sorts of images—the auditory, the visual, and the motor, which have their seats thus: the first in the cortical centres of hearing; the second in those of vision; and the third in those of motion." Tamburini first quotes Séglas as having described *psycho-motor verbal hallucinations*. He mentions four cases reported by Séglas who had this interesting hallucination. The first a woman, who labored under hallucinations of all the senses, among which were certain voices which obliged her to pronounce certain words against her will. At these times she felt that these voices were spoken in her mouth and she was constrained to move her tongue, but her mouth remained closed and no sound was uttered; she understood what they said "from the *movements of her own tongue*," to use her own words. A second case, a woman suffered from hallucinations of all the senses, and among these from voices; she had some which she perfectly distinguished from all others, because she did not hear them from her ears, but, as she said, by means of the *movements made within her*, which told her the words. A third case, of a paranoiac priest, who in addition to true auditory hallucinations, (telephonic voices,) had some of a *purely labial character*, which were accompanied by a slightly accentuated auditory sensation, but they chiefly consisted in movements of a verbal articulation. The fourth, a woman, feels within herself certain priests talking continually, but she does not hear their voices; she knows, however, what they are saying by the *motions which they provoke in her tongue*.

Tamburini then proceeds to give an account of a highly interest-

ing case observed by himself, which is quite typical. He points out that three of Séglas's cases do not present absolute neatness, as they are complicated with other hallucinations. This case, a female peasant, at the age of fifteen became melancholy and had hallucinations of voices which told her she was lost eternally. At the age of twenty-seven, soon after marriage, she again became melancholy without previous presentation in her mind of corresponding ideas; she perceives certain words "*forming themselves in her mouth*," (this is her expression.) In taking food, she felt these words *coming into* her mouth: "You may eat a serpent; you may swallow a live toad." When she prayed the words were maledictions and blasphemies against the Deity, and were formed in her mouth. This sensation was so vivid and overpowering that she was forced to repeat the words in a loud voice, and she fell in consequence into a state of mania and desperation. Later she became tranquil and gave a clear account of her hallucinations. She was no longer obliged to repeat aloud the voices (words?) which are *formed in her mouth*. She does not hear these words as if they were voices, but she feels them *forming in her mouth* as if she were pronouncing them without really doing so. She feels the words in the point of her tongue, which she feels to be in slight but continual movement. This movement is readily perceived by another, but the lips remain motionless. "But besides being convinced that these movements have more the character of a chronic spasm of separate groups of muscular fibres than of motions of articulation, even incipient, we are readily satisfied that this perception of the words is not closely colligated with such movements, for when the tongue is forcibly held motionless, she perceives them all the same." Still further, "when she really pronounces other words aloud, she feels under formation in her mouth the wonted ones of abuse, blasphemy, etc., etc." "In this case the part of contrast is also singular; the constant antithesis presented by those special hallucinations. Whatever she may be doing, whether eating, working or praying, the words are revilings, threats or bad wishes against her operations; and even when she hears the name of God or those of the Saints pronounced by other persons, she feels forming in her mouth blasphemies against them." "In this case there was neither visual nor acoustic hallucinations. Nor was there any idea of persecution. There was simply the perception of words which, as she said, she learned in her mouth; not in the form of voices, but by the sensation of a sort of slight



movements produced in her tongue, and she found these even when the tongue was engaged in the voluntary pronouncing of other words, or when it was forcibly held immovable outside the mouth. Here, therefore," he says, "we have a true motor verbal hallucination, that is to say, of words which are perceived solely by means of a sensation corresponding to that of the movements of articulation, which would be accomplished were the words actually pronounced, and they are equally perceived whether a sort of initial articulation is effected, or this does not take place at all." This is truly disappointing. He opens his paper with the distinct statement for which he claims originality, that hallucinations "essentially consist in an irritative state of the *psycho-sensory* centres of the cerebral cortex," and later says, "motor verbal hallucination, that is to say, of words perceived solely by means of a *sensation*, corresponding to that of the movements of articulation." It might be supposed that Tamburini used the term motor hallucination as a convenient one to avoid confusion, and really accepted the theory of the sensory character of our consciousness of movements, were it not that he devotes considerable space to this question, and gives the views of the eminent psychologists on this point, namely, Bain, Meynert, Strecker, Beaunis, Bastian, Cramer, Lewes, Spencer, Charcot and Wundt. The view of the latter he considers the most complete, which is that of the mixed theory of sensation and movement. Wundt holds it to be the result of three factors: First, of the sensation of pressure on the skin and subcutaneous parts. Second, the sensations of contractions of the muscles, (muscular sense, properly so called.) Third, the sensation of central innervation of the motor organs. But the difference between this view and those of Bastian and others is not so very great after all. We are certainly greatly indebted to Tamburini for his remarkably lucid and interesting report of this rare affection, and for the great depth of penetration shown by him in analyzing the symptoms in this case. Certainly, we could not have asked for a more clear illustration to defend the theory of the sensory nature of the so-called motor area. The fact is one of the most important contributions to psychological medicine of the past twenty years.







